CHAPTER SEVEN

Wetlands and Reefs: Two Key Habitats

The plants, predominantly grasses, that flourish in this environment (East Bay Wetlands) serve two biological functions: productivity and protection. From the amount of reduced carbon fixed by these plants during photosynthesis, this ecotone must be considered one of the most productive areas in the world and truly the pantry of the oceans. The dense stand of grass also represents a jungle of roots, stems, and leaves in which the organisms of the marsh, the "peelers," larvae, fry, "bobs," and fingerlings seek refuge from predators.

–Frank Fisher, Jr., *The Wetlands,* Rice University Review, 1972

The Galveston Bay system is composed of a variety of habitat types, ranging from open water areas to wetlands and upland grasslands. These habitats support specific plant, fish, and wildlife species and contribute to the tremendous diversity and overall abundance of bay life. Several specific habitat types have been identified and described in the Galveston Bay system (see FIGURE 2.4). The importance of these habitats, their internal functions, and their interconnectedness were presented in Chapter Three as a conceptual model of the bay ecosystem. The continued productivity and biological diversity of the estuarine system is dependent upon the maintenance of varied and abundant high-quality habitat.

Of the bay's habitats, two in particular are important to the health of the bay and are emphasized in this chapter. First, wetlands (including submerged aquatic vegetation) serve important biological, hydrological, and ecological functions in the bay ecosystem. Second, oyster reefs are important as indicators of the overall condition of the ecosystem and are the basis for an important commercial fishery. Besides the discussion presented here, note that several other chapters refer to other aspects of these habitats, such as the circulation effects of oyster reefs (Chapter Five), and the productivity of marshes (Chapter Eight).

WETLANDS

Wetlands are transitional areas between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water (Cowardin et al., 1979). Wetlands in Galveston Bay play several key ecological roles in protecting and maintaining the health and productivity of the estuary.

The Origin and Importance of Wetlands

Wetlands were formed in Galveston Bay from the long-term interaction of the ecosystem's physical processes. These processes include rainfall and runoff, water table fluctuations, streamflow, **evapotranspiration**, waves and longshore currents, astronomical and wind tides, storms and hurricanes, deposition and erosion, subsidence, faulting, and sea-level rise (White and Paine, 1992; see Chapter Five). These processes have formed an array of physical environments that range from being infrequently to permanently inundated with water. The resulting elevations of these environments range from submerged bay bottom, through the astronomical inter-tidal zone along the shore, to the higher wind-tidal zone and infrequently-flooded storm-tidal zone. The continuing action of physical processes and the proximity to salt and fresh water sources determine the location and composition of the plant communities that–more than any other attribute–define wetlands.

In addition to being formed by physical processes, wetlands have in turn become important elements of many processes that keep the bay ecosystem healthy. Hydrologically, wetlands fringing

Source: Galveston Bay National Estuary Program

Wetlands, shown here in Christmas Bay, are indispensable to ecosystem function. They provide nursery areas for marine species, feeding habitats for birds, and they export critical nutrients and organic matter to other bay habitats.

the shoreline are valuable filtering zones for polluted runoff and help protect the bay from excessive organic loadings from the land. Particularly in river bottomlands, they serve as good flood-control areas that release runoff water slowly to the bay compared to the rapid discharge from man-made drainage systems. The relatively long residence times associated with wetlands help to treat the water by removing organics and permitting excess sediment to settle out before reaching the bay. Finally, well-developed vegetated wetlands also provide a barrier between open water and land, preventing or reducing shoreline erosion.

Biologically, marshes are an important source of nutrients and carbon exported to biological consumers in open bay waters and the bay bottom. Wetlands are among the most productive biological systems on the planet, and they may be more important to the Galveston Bay system than is true for many other bays (Sheridan et al., 1989 and Chapter Eight).

Among the most important wetland functions is their role as habitat for many species of plants, fish, birds, and wildlife. Many of Galveston Bay's principal fishery species rely on wetlands during at least some part of their life cycle. These species include brown shrimp, white shrimp, blue crab, red drum, spotted seatrout, southern flounder, and Gulf menhaden. In the same way, wetlands are important nurseries to hundreds of non-commercial species, ranging from microbes to vertebrates, that comprise a large part of the food web (see Chapter Three). Several bird species, such as snowy egrets, roseate spoonbills, tricolored herons, black skimmers, and great egrets use the marsh as feeding habitat.

General Classification

For convenience, wetlands and aquatic habitats can be classified in five overall categories:

Estuarine systems (salt or brackish water)

Palustrine systems (generally fresh water)

Lacustrine systems (lakes)

Riverine systems (rivers)

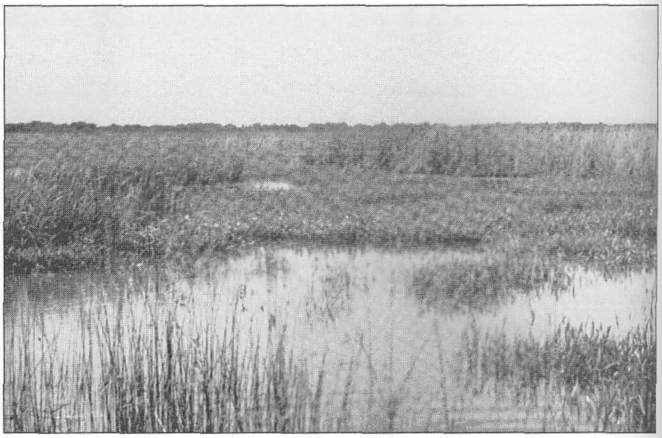
Marine (open ocean)

The estuarine system dominates Galveston Bay wetlands, comprising 89 percent of the wetland and deep-water habitats in 1989 (White and Paine, 1992; White et al., 1993). The palustrine system was a distant second at six percent, followed by the lacustrine (four percent), riverine (0.5 percent), and marine (0.4 percent) systems.

Within this classification scheme, wetlands can be further

Source: Bureau of Economic Geology

Brackish-marsh community in the Brazoria National Wildlife Refuge southwest of Hoskins Mound. Although dominant species are Spartina patens *and* Distichlis spicata, Spartina alterniflora *occurs along the tidal channel.*



Source: Bureau of Economic Geology

Fresh-marsh community in the Trinity River valley north of Interstate Highway 10.

Source: Texas Parks and Wildlife Department

Cypress swamps, bottom-land hardwoods, and associated riparian (floodplain) forests, contribute important nutrients as well as dissolved and particulate organic matter to the estuarine system. In addition, they provide valuable habitat supporting numerous fish and wildlife species. Mature bottomland forests are of prime concern on a national basis due to their accelerating loss and high habitat value.

subdivided into hydrologic subsystems, such as intertidal and subtidal, and into classes based on vegetation and substrate. It should be noted that this classification of wetlands does not necessarily coincide with "jurisdictional" wetlands subject to Corps of Engineers jurisdiction under Section 404 as determined by the *1987 Wetland Delineation Manual.* Wetlands encompass a variety of plant communities. In Galveston Bay, five community types dominate: emergent wetlands including salt-water marshes, brackish water marshes, and fresh-marshes; forested wetlands (swamps); and submerged aquatic vegetation beds (such as seagrass beds). These communities are described below.

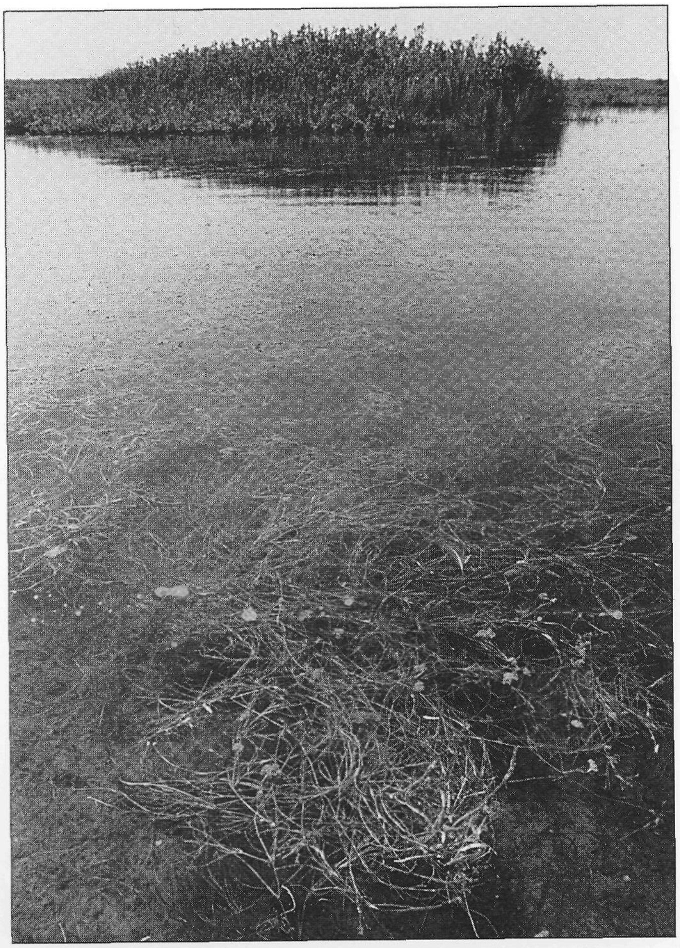
Salt Marsh

Salt-marsh communities are found in high-salinity areas, along protected estuarine shorelines. Prevalent species in the salt-marsh community include *Spartina alterniflora* (smooth cordgrass), *Batis maritima* (saltwort), *Distichlis spicata* (saltgrass), and *Salicornia spp.* (glasswort). *S. alterniflora*, which lives in the intertidal zone, dominates the low-salt-marsh community. At higher elevations, *Spartina patens* (marshhay or saltmeadow cordgrass) and *Spartina spartinae* (Gulf cordgrass) occur, although they are more common in brackish marshes (White and Paine, 1992).

In wind-tidal sand flats, vegetation is limited because of intermittent salt water flooding and subsequent evaporation that concentrates salt. Algal mats are abundant in these areas, while emergent vegetation is limited to salt-tolerant species such as shoregrass (*Monanthochloe littoralis*), saltwort, and glasswort (White and Paine, 1992).

Brackish Marsh

This community inhabits the transitional zone between salt marsh and fresh marsh and is affected by a widely varying range of water levels and salinities. As would be expected, a number of species utilize this habitat, ranging from near-fresh water to salt-marsh species. In general, the brackish marsh is dominated by *Spartina patens* (marshhay or salt meadow cordgrass) and *Distichlis spicata* (seashore saltgrass; Harcombe and Neaville, 1977). Other species include needlegrass rush (near tidal drains), common reed and big cordgrass (on levees), seashore paspalum and longtom (in fresher areas), and isolated clumps of saltmarsh bulrush and Olney bulrush.



Source: Galveston Bay National Estuary Program

Submerged meadows composed mainly of widgeon grass and shoalgrass are a key element of the lower bay environment, shown here in Christmas Bay. Only a remnant of this habitat type remains baywide, the destruction resulting from a combination of locally increased turbidity, increased bay depth, high pollutant loads, fishing and boating disturbance, dredging, and tropical storms and hurricanes.

Fresh Marsh

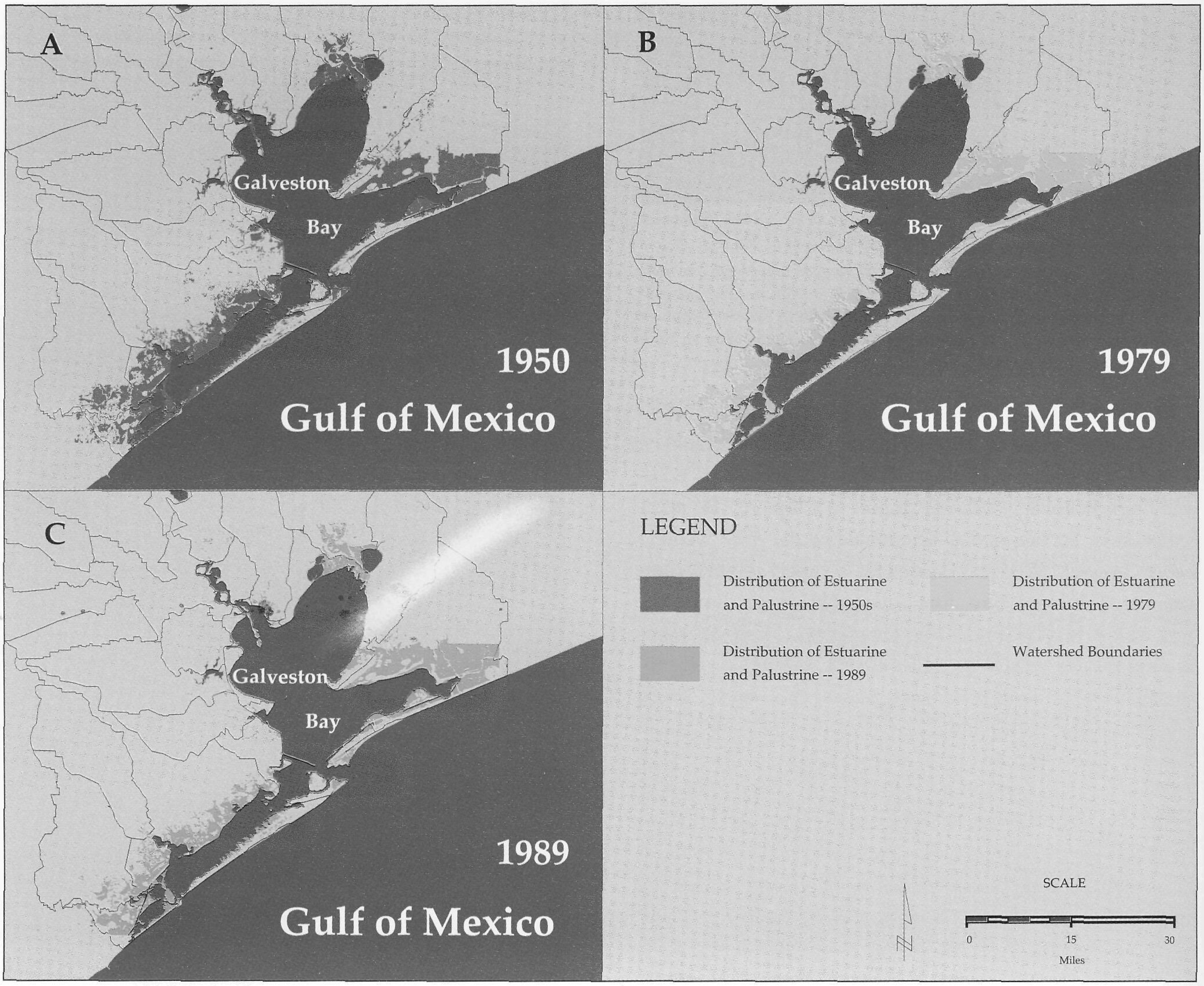
Fresh marshes are primarily found in areas that are affected by saltwater flooding only during large tropical storms or hurricanes. The fresh water in these marshes is sufficient to maintain a low enough salinity for such species as *Zizaniopsis miliacea* (marsh millet or giant cutgrass), *Sagittaria falcata* (coastal arrowhead), and *Eleocharis quadrangulata* (squarestem spikesedge). In lower, wetter areas, water hyacinths can be found, while panic grasses and spiny aster can be found in higher areas. Shrubs become established around the margins of the marsh (White and Paine, 1992).

Swamps

Forested wetlands include woodlands or forested areas with saturated soils or which are inundated by water much of the year. In the Galveston Bay system, this community is located almost exclusively in the Trinity River valley. The swamp community primarily consists of *Taxodium distichum* (bald cypress), with some button bush, water elm, and water hickory (White and Paine, 1992).

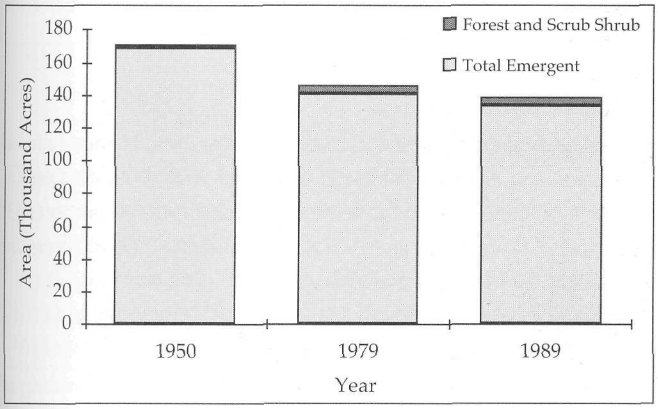
Submerged Aquatic Vegetation

Historically, continuous beds of submerged aquatic vegetation flourished in three locations: 1) around the Trinity River Delta, consisting of *Ruppia maritima* (widgeon grass), and *Vallisneria americana* (tape grass); 2) along the west shoreline from Seabrook to San Leon, also consisting of widgeon grass; and 3) the southern shoreline of West Bay, with relatively long narrow beds of *Halodule wrightii* (shoalgrass) mixed with widgeon grass (Renfro, 1959; Pullen, 1960). A remnant of this latter habitat can be still be found in Christmas Bay, with shoalgrass and widgeon grass being the primary species. *Halophila engelmannii* (clovergrass) and *Thalassia testudinum* (turtlegrass) are also found, but to a limited extent (Pulich and White, 1991). *Thalassia* and perhaps other seagrasses ocurred in West Bay, but are now gone (Pulich and White, 1991). Submerged aquatic vegetation does not normally fall within the def-



Source: White et al., 1993

FIGURE 7.1. Changes in the distribution of emergent wetlands bordering Galveston Bay since the 1950s. Wetland types mapped include estuarine (salt or brackish water) and palustrine (generally fresh water). These maps are based on a digitized wetlands classification of aerial photographs.



Source: White et al., 1993

FIGURE 7.2. Changes in the extent of wetlands in Galveston Bay over time. The figures reveal an overall loss of 17 to 19 percent of the wetlands present in 1950, but encouragingly, the rate of loss has declined.

inition applied to emergent wetlands like salt marshes, but their high importance and severe declines in the Galveston Bay system make them quite important in this system.

The Need to Determine Wetland Status and Trends

Understanding where wetlands are located and how they have changed over time is critical if they are to be effectively protected and managed. Some broad trends are available to characterize wetland losses. For example, nationally, three-fourths of the estuarine wetlands classified by Dahl and Johnson (1991) were "intertidal emergent," typified by *Spartina* salt marshes. These authors estimated a relatively small 1.5 percent loss from the mid 1970s to the mid 1980s for this important habitat type, nationwide.

For Galveston Bay, most scientists suspected emergent wetlands were being lost at a rate higher than the national trend. However, until recently, no figures have been available to characterize losses. To provide this needed information, the Galveston Bay National Estuary Program commissioned a study by White et al. (1993) to determined the status and trends of Galveston Bay wetlands.

In the study, wetlands were delineated on aerial photographs through stereoscopic interpretation using procedures developed for the U. S. Fish and Wildlife Service National Wetlands Inventory program. Field reconnaissance was an integral part of the interpretation process. Following the classification procedures of Cowardin et al. (1979), wetlands were classified by system, subsystem, and class for the 1950s, 1979, and 1989, and by subclass, water regime, and special modifier for the years 1979 and 1989 (White et al., 1993). Upland habitats were delineated on 1979 and 1989 maps. More than 180 field sites were examined as part of an effort to characterize wetland plant communities and define wetland map units in the Galveston Bay system (White and Paine, 1992). Most of the following discussion summarizes the results from this comprehensive study.

Distribution of Wetland Communities

Based on the work of White et al. (1993), vegetated wetlands were found to total 138,600 ac (216.6 sq mi), or about 25 percent of all of the open-bay and adjacent bay habitats. As would be expected, the majority of these wetlands were estuarine intertidal emergent wetlands (salt or brackish marshes) and constituted 83 percent or 108,200 ac. Palustrine emergents (fresh or inland marshes) comprised 22,200 ac. The total area of forested wetland habitat amounted to 5,650 ac, or four percent of the vegetated wetland system. Fresh water scrub/shrub wetlands totaled 2,000 ac (less than two percent of vegetated wetlands), and estuarine scrub/shrub wetlands encompassed 550 ac (0.4 percent). Areal extents of the various types are shown in FIGURE 7.1, while trends are summarized in FIGURE 7.2.

Submerged aquatic vegetation had a total mapped area of 700 ac (adjusted for photo-interpretation errors) in the Galveston Bay project area (White et al., 1993). Of this total, 386 ac were mapped in Christmas Bay, with most of the remaining areas near the Trinity River delta. The total area of submerged vegetation is thought to be larger than actually measured because of unmappable areas on the margins of the Trinity River delta.

Wetlands Loss Over Time

Overall Trend

The aerial photo-interpretation analyses performed by White et al., (1993) indicated gains and losses in different classes of wetlands, with an overall net decreasing trend since the 1950s (see FIGURE 7.2). More than 33,000 ac of vegetated wetlands have been lost during this period, amounting to about 19 percent. (The actual loss in all wetlands is somewhat less, perhaps closer to 17 percent, because delineations of wetlands in some areas on the 1950s vintage black-and-white aerial photographs included peripheral upland areas, which inflated the 1950s wetland acreages).

This rate of loss is substantially higher than the national rate of loss of estuarine wetlands. One encouraging sign, however, is that the rate of loss decreased over time from 1,000 ac/yr between 1953 and 1979, to about 720 ac/yr between 1979 and 1989. The rate of loss between 1979 and 1989 is even lower (<500 ac/yr) if inaccuracies in wetland interpretation of the 1979 photographs are taken into account.

The area of mapped emergent wetlands (marshes) decreased from 165,500 ac in the 1950s to 130,400 ac in 1989, producing a bay-wide net loss of 35,100 ac, or 21 percent of the 1950s resource (FIGURE 7.3 indicates the several types of losses). As in the case of vegetated wetlands, this amount of loss in emergent wetlands is thought to be overestimated; the actual loss is probably less than 19 percent.

Trend by Wetland Classes

A large portion of the overall losses in wetlands, can be attributed to the loss of fresh-water marshes (TABLE 7.1 and White et al., 1993). Note that the values show the net loss and gain for each type of wetland as opposed to a gross loss. The apparent increase in "estuarine bay marshes, salt and brackish water" areas are in large part due to reclassification of fresh-water marshes and other marsh types to this category.

Total scrub/shrub wetlands decreased by 900 ac, representing a 25 percent loss of the 1950s resource. Forested wetlands, on the other hand, increased by 3,600 ac–almost twice the 1950s area. Almost all of this gain was in the Trinity River valley. Much of the gain in forested wetland area was due to: 1) growth of shrubs and trees in areas previously mapped as scrub/shrub wetlands; and 2) photointerpretation inconsistencies on the different sets of photographs. In addition, most of the forested wetland gain since the 1950s was due to the invasion of Chinese tallow, an exotic species with rapid growth potential and low wildlife value. Some losses were due to changes in hydrology.

Submerged aquatic vegetation habitat decreased from 2,500 ac in the 1950s to 700 ac in 1987 (FIGURE 7.4). Accordingly, the decline in this habitat type is 1,800 ac, or over 70 percent of the 1950s habitat (White et al., 1993).

Causes of Wetlands Loss

Four main causes of the wetland losses are: 1) man-induced subsidence and associated relative sea-level rise; 2) direct conversion for agricultural, urban, industry, and transportation purposes; 3) dredge-and-fill activities; and 4) isolation projects. These factors are discussed in more detail below.

Effect of Subsidence and Sea Level Rise

Subsidence and sea level rise has resulted in the drowning of numerous wetland areas throughout the bay system, and has also

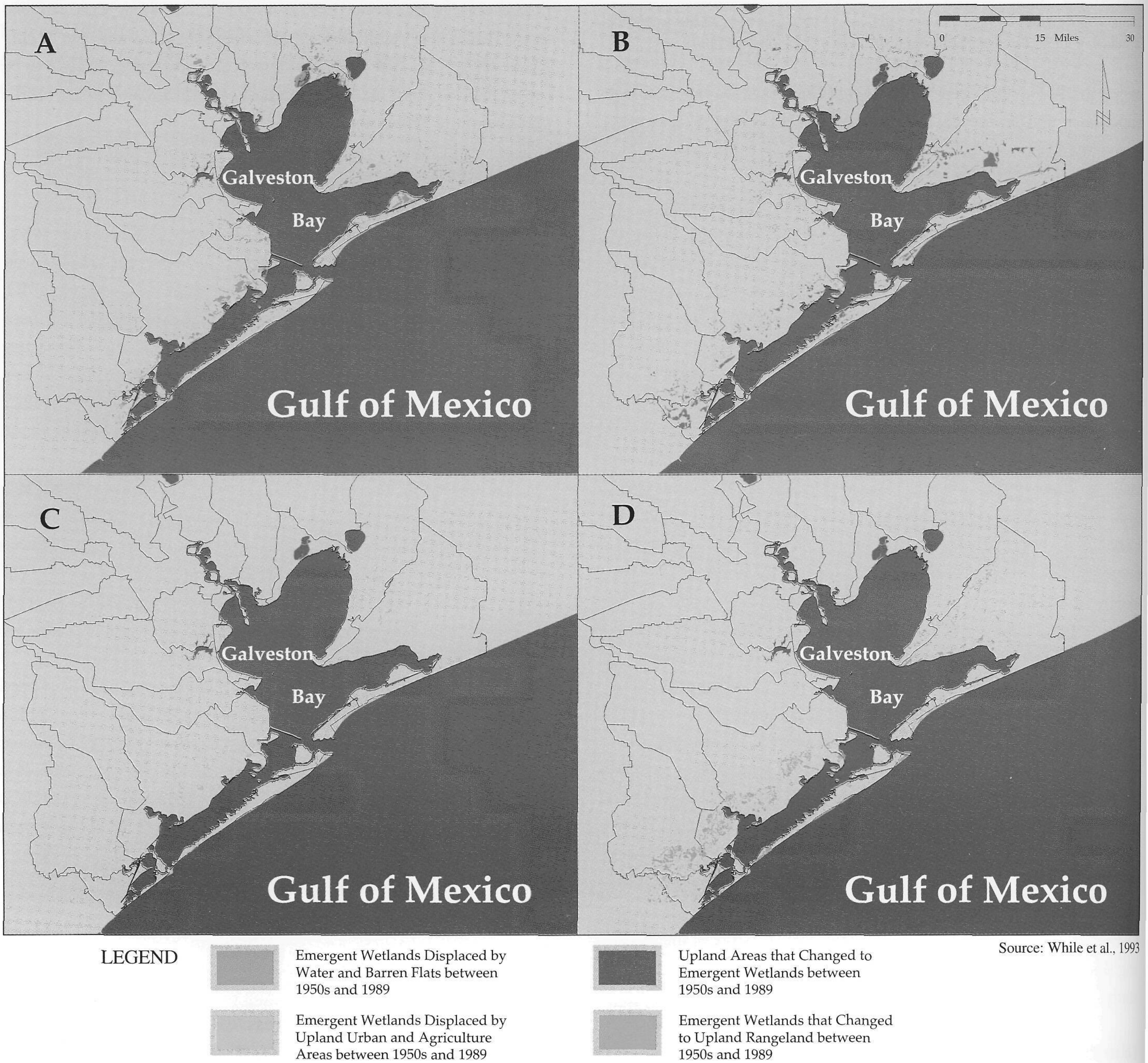


FIGURE 7.3. Types of wetland conversions taking place from the 1950s to 1989. Leading causes of wetland losses were conversion to open water and barren flats, and conversion to rangeland (also see FIGURE 7.7).

TABLE 7.1. Estimated Net Change in Areas of Vegetated Wetland Classes Between 1950s and 1989.

Wetland Class	Net Change in Wetland Area 1950s-1989(ac)
Estuarine bay marshes, salt and brackish water[1]	+ 8,200
Estuarine bay marshes, salt and brackish water/unconsol. shore	-16,200
Estuarine, intertidal scrub/shrub	+ 4,700
Fresh-water marshes, meadows, depressions, or drainage areas	-26,800
Swamps, woodlands in floodplains, depressions, meadow rims	+ 3,500
Willow thicket, river banks	- 1,400

Source: White et al., 1992

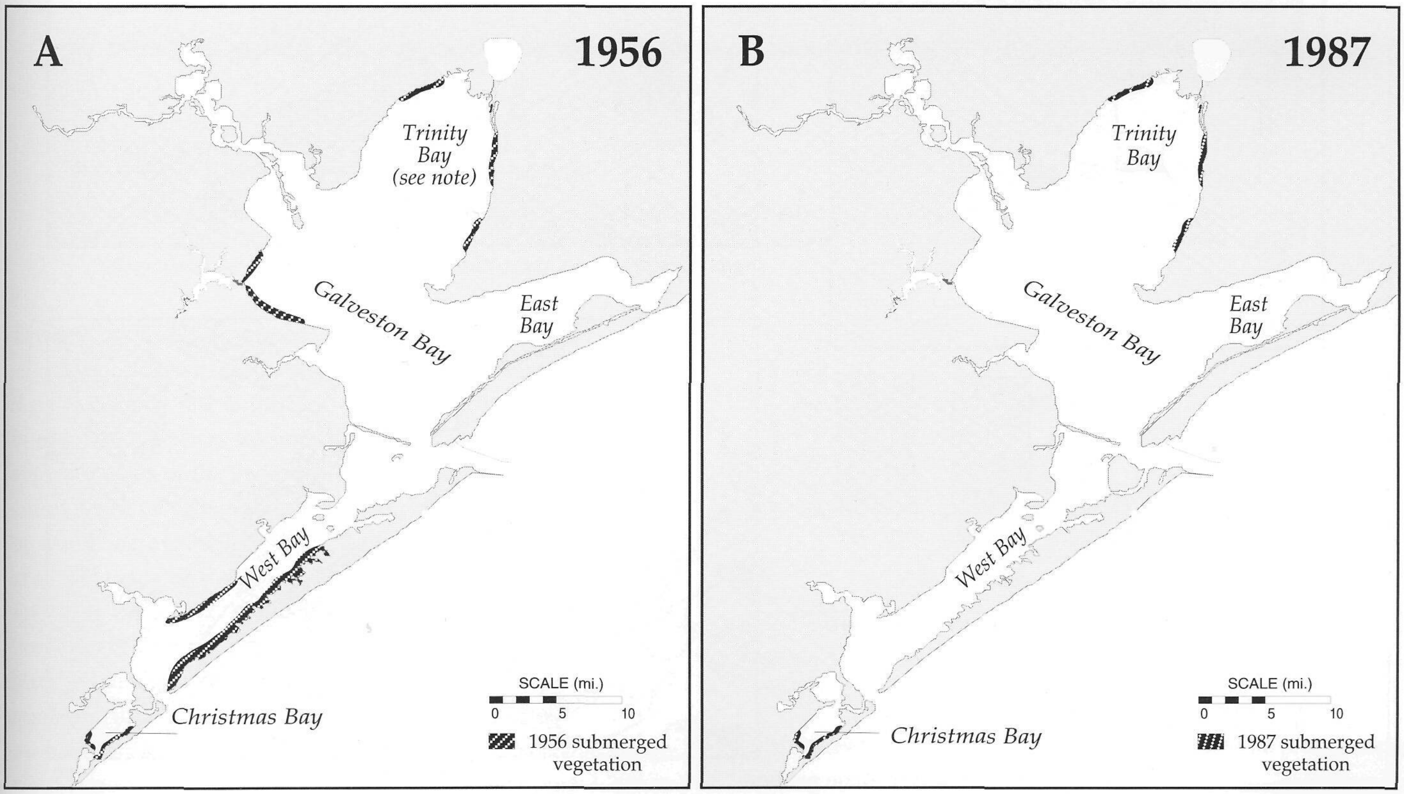
[1]The apparent increase in "estuarine bay marshes, salt and brackish water" areas are in large part due to reclassification of fresh-water marshes and other marsh types to this category

resulted in creation of new wetlands by inundation of uplands. Overall, losses exceed gains. About 26,400 ac of 1950s marsh were converted to open water/barren flat habitats by 1989 (see FIGURE 7.3a). Most of this conversion was due to subsidence caused by pumping of groundwater and relative sea level rise combined with consolidation (shrinking) of clay layers in the underlying aquifers (see Chapter Five).

In certain parts of the bay system, the effects of man-induced subsidence and associated relative sea-level rise have been particularly severe. Wetland areas affected by subsidence include the north, west, and south margins of Galveston Bay and the northeast part of West Bay. For example, more than 3,600 ac of marshland in the Virginia Point area (Jones Bay and Swan Lake) were replaced by open water and barren mud flat between the 1950s and 1989 (FIGURE 7.5).

The Clear Lake area offers another example of the effect of land-surface subsidence and the subsequent intrusion of open water and shallow flats into vegetated wetlands (FIGURE 7.6). Since the 1950s, there has been a complete loss of fresh water wetlands along Armand Bayou (McFarlane, 1991). Subsidence along active surface faults also contributed to replacement of marshes by water and barren flats in some areas.

Losses in emergent wetlands in some areas were partly offset by gains in emergent wetlands in other areas. Bay-wide subsidence/sea level rise was probably responsible for converting part of approximately 21,000 ac of previously upland areas to wetland areas (see FIGURE 7.3b). Some conversion of uplands to wetlands were the result of water management programs implemented in national wildlife refuges. Regionally, these increases in marsh were most pronounced inland from East Bay, on Galveston Island, and inland from West Bay and Christmas Bay. The conversion of uplands to wetlands generally took place in transitional areas peripheral to existing wetlands. Additional increases in emergent wetlands resulted after emergent vegetation spread



Source: Pulich and White, 1991

FIGURE 7.4. Locations and losses of submerged aquatic vegetation in Galveston Bay. Best estimates indicate at least a 70 percent loss of this habitat type. Although present, submerged aquatic vegetation was not mapped in Christmas Bay and Trinity Bay locations in 1956. The 1987 distribution of submerged vegetation in these locations is shown for comparison purposes.

over areas previously mapped as intertidal flats. This type of change was common in intertidal sand flats on the barrier islands.

Conversion to Upland Land Uses

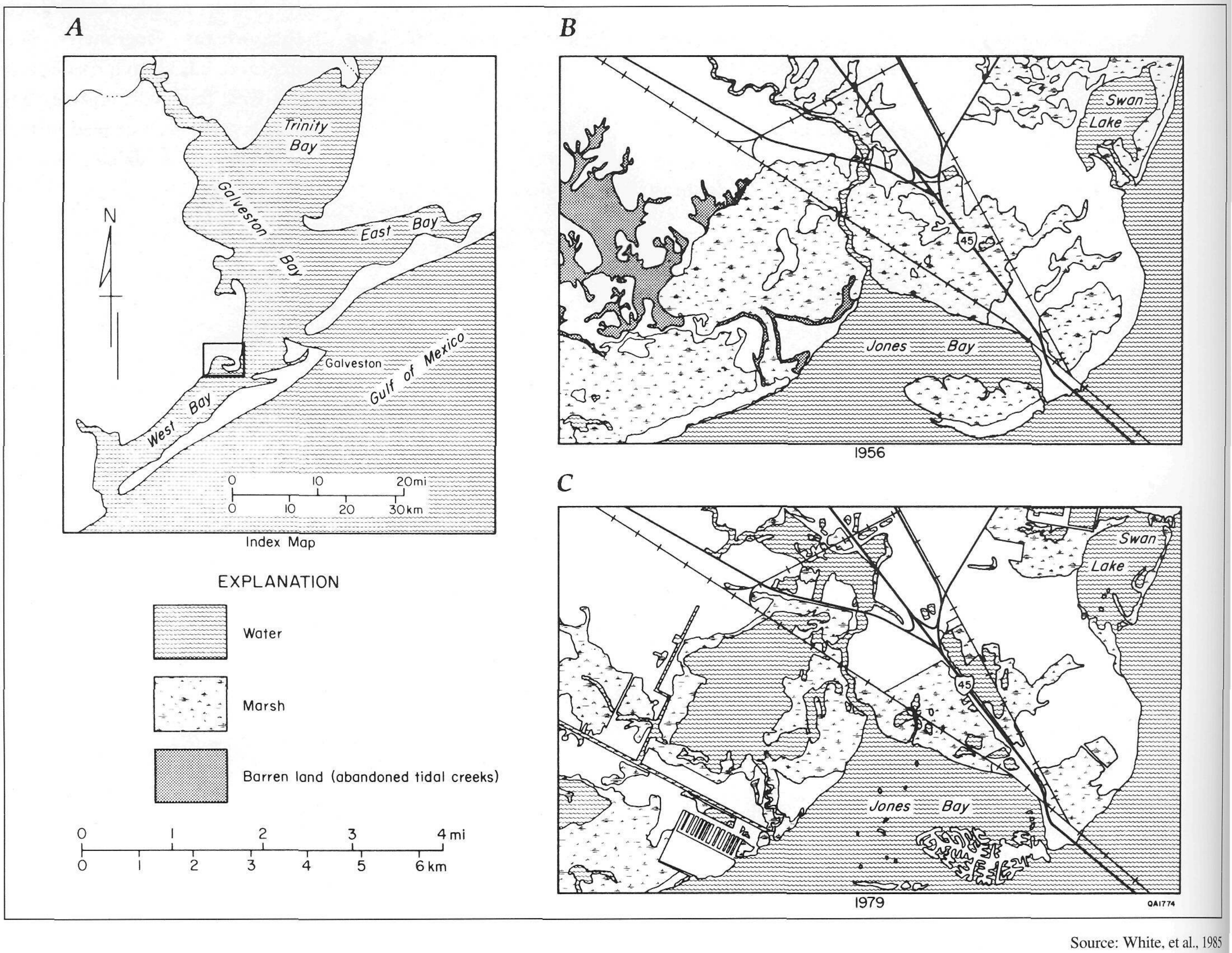
Draining of wetlands has also caused a significant loss of wetlands since 1950 (see FIGURE 7.3c). Much of this loss has occurred in fresh water marshes as opposed to the saltwater or brackish marshes. The gross lost area is 35,600 ac, which accounts for much of the total loss in estuarine and fresh water emergent wetlands. It should be noted that part of this loss can be attributed to photo-interpretation problems.

Conversion to upland range was the most significant human land use change affecting wetlands, with 25,000 ac of wetlands lost between the 1950s and 1989 (FIGURE 7.3d; FIGURE 7.7). Most of this change occurred landward from West and Christmas Bays. While some of the conversion appeared to be natural, much of the change may be attributable to drainage ditches constructed to reduce flooding and increase the area available for livestock grazing.

Conversion to cropland and pastureland claimed 3,600 ac, mostly in the Hitchcock, Oyster Bayou and Hoskins Mound areas. Most of the new cropland area was for rice cultivation. Although some of these wetland conversions to uplands were related to natural conditions, such as annual (and seasonal) changes in moisture levels which affected photointerpretation, most of the loss may be due to direct conversion to upland range and cropland.

Conversion of wetlands to urban upland areas totaled 5,700 ac, and were concentrated in the south and west side of the bay, particularly around the Virginia Point area. Other areas where urbanization of wetlands occurred were in the Galveston, Texas City, League City, and Sea Isle areas.

Other upland conversions since the 1950s included dredged material disposal areas, with a net loss of 500 ac, and conversion to oil and gas production, resulting in a net loss of 800 ac. Much of the dredged material disposal losses were associated with the Gulf Intracoastal Waterway, while oil and gas production losses were concentrated in the Virginia Point, Texas City, and High Island areas.



Source: White, et al., 1985

FIGURE 7.5. Changes in the distribution of wetlands between 1956 (b) and 1979 (c) near Jones Bay and Swan Lake, shown inset in (a). Land subsidence due to groundwater pumping resulted in the drowning of some 3,600 ac of marshland.

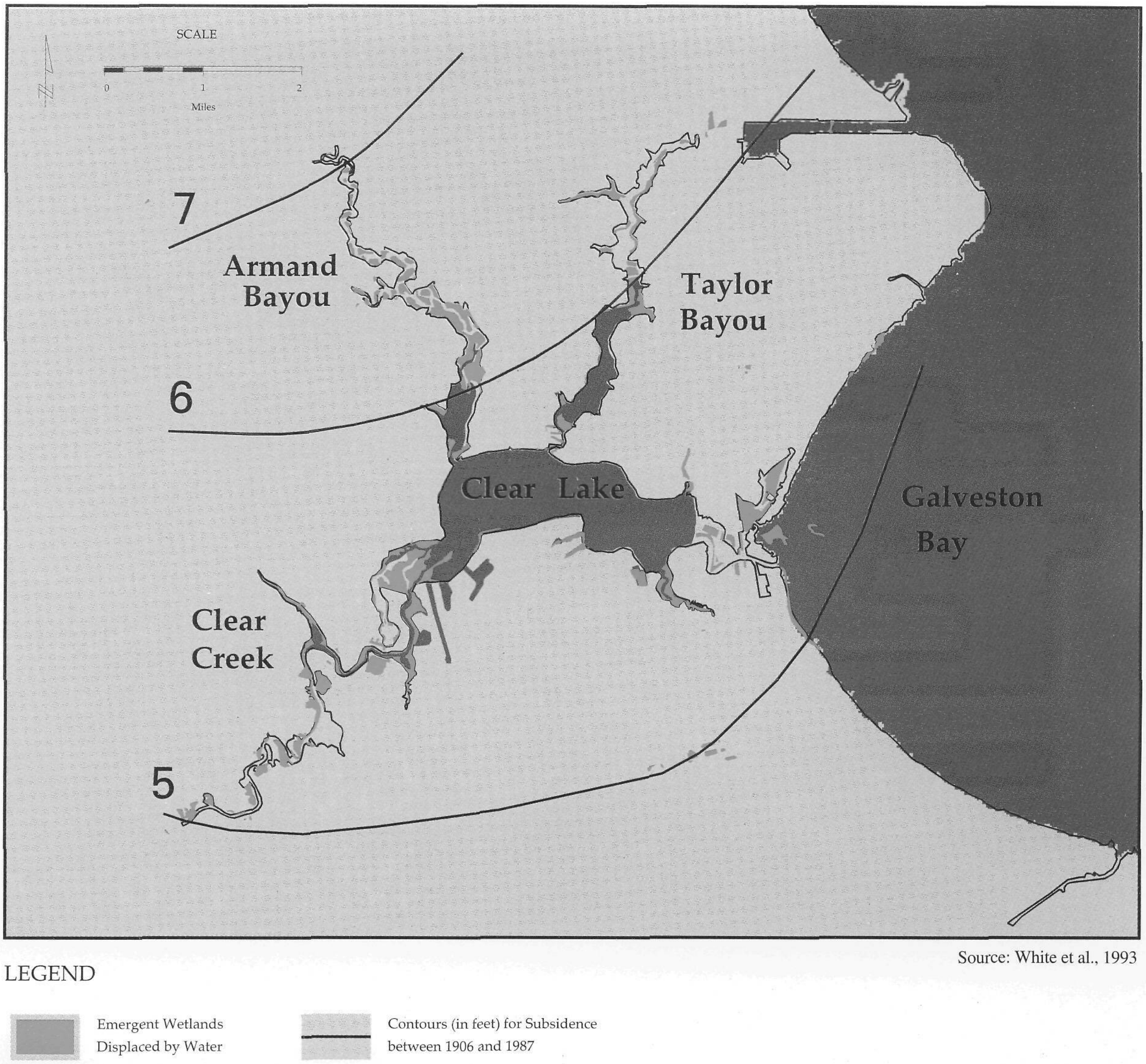
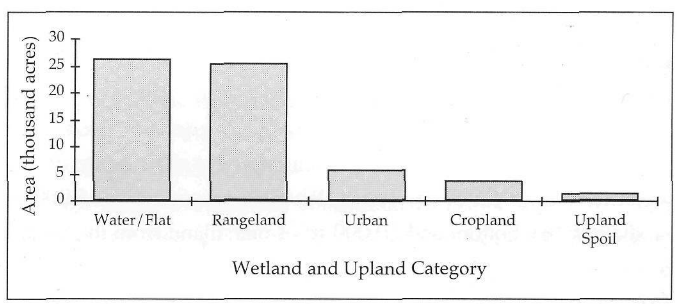


FIGURE 7.6. *Relationship between subsidence and losses of emergent wetlands in the Clear Lake system. Contours indicate subsidence in feet between 1906 and 1987. Red indicates emergent wetlands displaced by open water. The loss of wetlands along Armand Bayou was practically complete, as a result of the increase in water depth.*

Dredge and Fill Influences

The relative impact of dredging and filling on marshes is difficult to quantify due to the lack of a good early-century baseline. In addition, there was no regulatory protection of wetlands until implementation of the Section 404 program in 1972. Ward (1993) estimated the total loss in marshland due to dredge and fill activities by analyzing available records from federal dredging projects, available maps of the bay over time, and U.S. Army Corps of Engineers Section 10/404 dredge-and-fill permits since the 1940s (see Chapter Five for more discussion of Section 10/404 projects). Based on this information, he estimated that a total of 7,070 ac of marshland had been lost to dredging, filling, and disposal activities since 1900. Of this loss, 2,920 ac was lost due to creation of designated disposal areas, 860 ac to navigation channels, and 3,290 to private dredge and fill operations under the Corps Section 10/404 permit program (note that the Section 10/404 permit data only extend back to the 1940s). The total area of wetlands lost was up to five percent of the total wetland area estimated to be present representing up to 20 percent of the net losses.



Source: White et al., 1993

FIGURE 7.7. *Extent of Galveston Bay marshes converted to other types of habitats.*

Isolations

As described in Chapter Five, several large-scale modifica-

Source: Powell et al., 1994

FIGURE 7.8. Oyster reefs and shell-dominated bottom in Galveston Bay, shown in red. This map is based on a survey which used state-of-the-art sonar, global positioning, and geographic information system technologies.

tions to the bay's shoreline have resulted in large areas of open bay and marshland being isolated from the bay itself. The most significant of these was the closure of Turtle Bay (now called Lake Anahuac) in 1936. Ward (1993) estimated that the closure of this area near the mouth of the Trinity River eliminated about 6,000 ac of shallow bay bottom and 10,000 ac of marshland from the estuarine system. Other estuarine marshlands that have been isolated from the bay include:

1,100 ac in the Trinity River delta for the Delhomme hunting area;

2,500 ac on the west side of Trinity Bay and Trinity River delta for HL&P Cedar Bayou Generating Station's cooling pond;

About 2,000 ac on the north shore of East Bay for salt water barriers; and

About 700 ac in the Moses Lake and Dollar Bay area for the Texas City flood control project (although some limited exchange with bay waters occurs).

While these isolation projects have not resulted in a total conversion of these marshes to upland land uses, there has been an overall reduction of 16,000 ac of estuarine marshland from the Galveston Bay system since 1900 due to isolation and open-water habitat (Ward, 1993).

Changes in Submerged Aquatic Vegetation

The exact reasons for the decline in submerged aquatic vegetation are not known, although they may include some of the mech-

TABLE 7.2. Areal Extent of Oyster Reefs in Galveston Bay, Comparing 1971 and 1991 Survey Results.

Location	Extent of Reef 1991 (ac)	Contrast Between Comparable Reef Areas[1] Mapped in 1971 and 1991 1971 (ac)	1991 (ac)	1971-1991 % Increase
East Bay	2,900	2,660	2,900	9.0
Trinity Bay	1,250	540	840	55.6
Redfish Bar	3,300	1,850	3,090	67.0
North Redfish Bar in Central Galveston Bay	1,430	400	700	75.0
Red Bluff/Morgans Point Embayment	300	150	200	33.3
Clear Lake Embayment	270	220	260	18.2
Dickinson Embayment	2,100	1,370	1,910	39.4
Pelican Island Embayment	2,070	N/A	N/A	N/A
West Bay	7,400	N/A	N/A	N/A
West Bay Satellite Bays	2,980	N/A	N/A	N/A
Houston Ship Channel	2,700	240	1,310	445.8
TOTAL	**26,700**	**7,430**	**9,300**	**25.2**

Source: Powell et al., 1994

[1]See text for discussion of differences in methodology between the 1971 and 1991 surveys.

anisms described above. Pulich and White (1991) suggested that the most plausible reasons included: 1) subsidence and Hurricane Carla in western Galveston Bay; and 2) human activities including development, wastewater discharges, chemical spills, and dredging activities in West Bay. Czapla (1993) indicated that light attenuation (the reduction in light penetration) was presumably the major limiting factor to submerged growth in Galveston Bay, as in other estuaries. In addition, submerged aquatic vegetation requires a low-energy environment with limited erosional forces. Subsidence has removed natural submerged wave barriers (**berms**) which created protected areas for submerged aquatic vegetation. Increased wave energy and erosional forces experienced in locales where submerged aquatic vegetation formerly existed may have reduced the potential for re-establishment.

OYSTER REEFS

As described in previous chapters, oysters create reef habitats that are important from a commercial, hydrological, and ecological point of view. Reef and unconsolidated shell sediments comprised a total of 26,700 ac in 1991 (Powell et al., 1994). The oyster reefs of Galveston Bay can be divided into naturally-occurring reefs that have existed over historic time, and reefs that originated through human influences.

Natural reefs are primarily of four types: 1) longshore reefs oriented parallel to shore and located near or attached to the shoreline; 2) reefs extending perpendicular from the shoreline or a point near shore out into the bay; 3) patch reefs composed of one or more relatively small more-or-less circular bodies; and 4) barrier reefs extending across or nearly across the bay.

Reefs originating from human influences include those associated with: 1) dredged material banks next to navigation channels; 2) oil and gas development; 3) oyster leases; and 4) natural accretion in areas not previously conducive to reef development because of modifications in current flow. The reef types resulting from human activity account for a substantial fraction of all of the present-day reefs in Galveston Bay. In many areas of the bay, they account for 80 to 100 percent of the entire reef area.

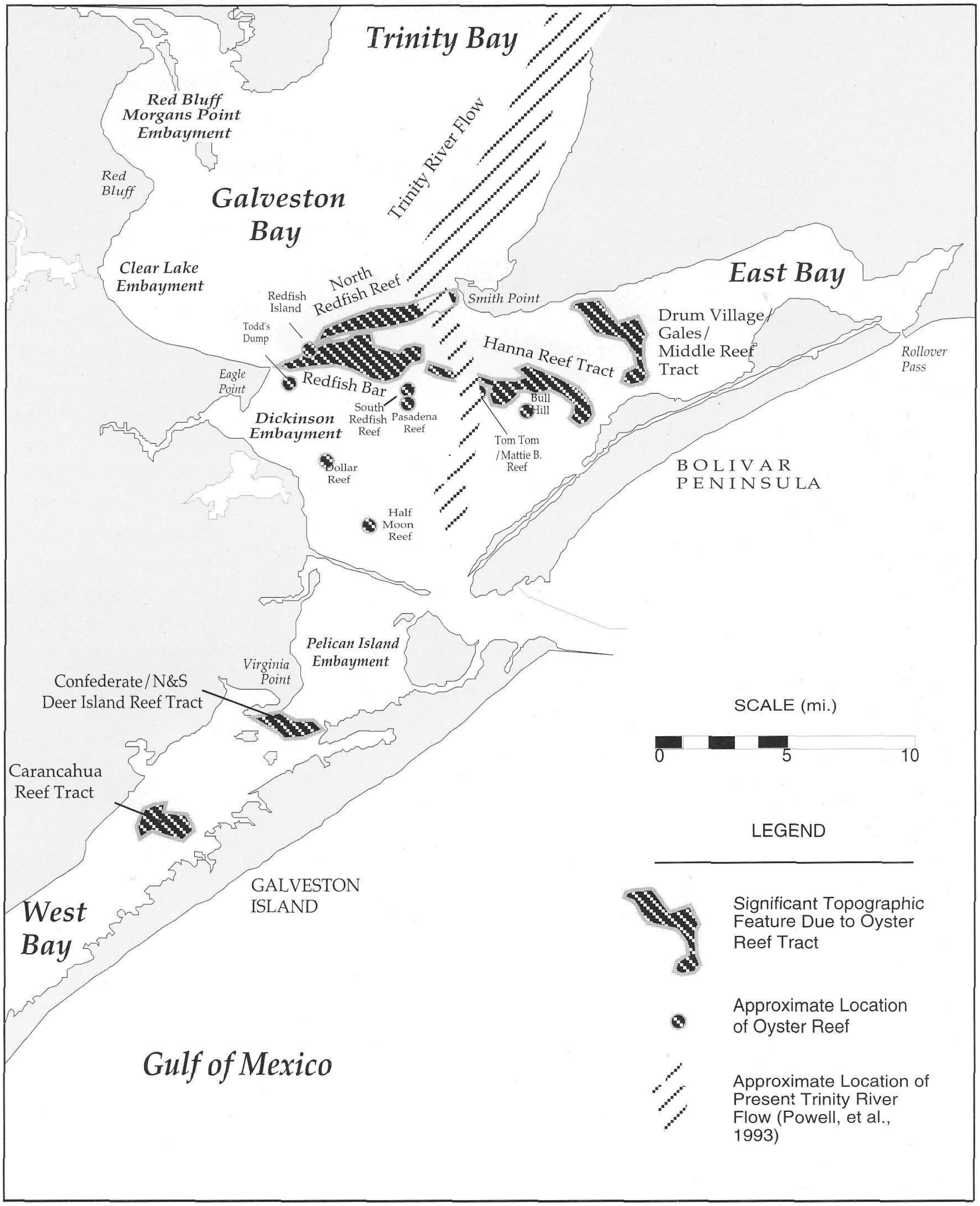
Reef Distribution and Trends

Oyster reefs and shell-dominated bay bottom were surveyed by Powell et al. (1994). The surveyed area included the majority of West Bay, East Bay, Trinity Bay, and Galveston Bay. Of the surveyed area, about 53 percent was in Galveston, East and Trinity Bays. The remaining 47 percent was in West Bay and the Pelican Island Embayment (the term embayment refers to sectors of Galveston Bay proper separated by significant points, islands, or man-made dikes and channels). A summary of the report prepared by Powell et al. (1994) is presented below. Chapter Eight includes a discussion of the status and trends of the oyster as a species, while this discussion emphasizes the habitat value of oyster reefs.

Locations of reefs and unconsolidated shell sediments in the bay are indicated in TABLE 7.2, FIGURE 7.8 (detailed locations), FIGURE 7.9a (general locations with reef names), and FIGURE 7.9b (reef gains and losses).

The area of oyster reef and oyster shell bottom identified in the recent oyster survey was substantially greater than depicted on earlier Texas Parks and Wildlife Department charts from the 1970s prepared by Benefield and Hofstetter (1976). Comparing all but the West Bay area, the recent survey identified 14,210 ac of oyster reef compared to the 7,424 ac of reef measured by the 1976 study. Reef accretion was most noticeable in three areas: 1) along open-bay reaches of the Houston Ship Channel; 2) at the southern edge of Redfish Bar and the Bull Hill extension of the Hanna Reef tract; and 3) in the Dickinson Embayment (FIGURE 7.9b). Reef loss, although minor overall, was concentrated in three areas: 1) along the southern shore of Trinity Bay; 2) in the Mattie B./Tom Tom Reef area at the northern end of the Hanna Reef tract; 3) and in the inner portion of the Clear Lake Embayment.

The greater extent of reef identified by Powell et al. (1994) can be ascribed to several factors. Some new reef formation has probably occurred in the ensuing 20 years since the Texas Parks and Wildlife Department study was completed. However, technology used by Powell et al. allowed more extensive mapping of the bay (particularly in deeper areas) than was previously possible using primarily manual and visual methods. Existing information, including the wisdom of working oystermen, indicates that little



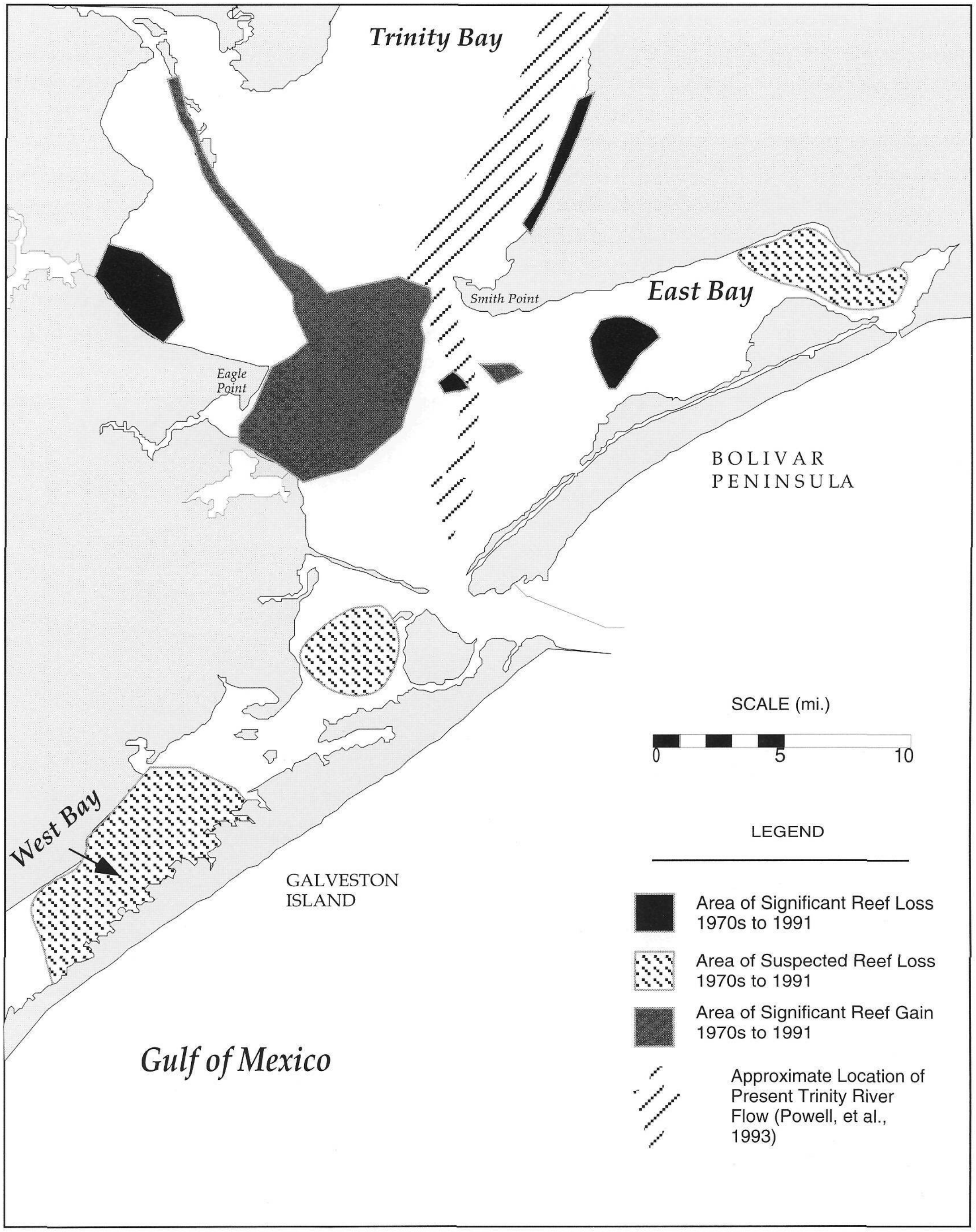
Source: After Powell et al., 1994

FIGURE 7.9a. *Diagrammatic representation of major Galveston Bay oyster reefs. Commercial and other named reef tracts are identified in relation to net Trinity River current flow. Significant oyster reef gains and losses, 1970s to 1991, are shown in (b).*

loss of previously-mapped reef has occurred over the last 20 years. Those few areas where reef decline has occurred can be ascribed mainly to regional subsidence and burial by sedimentation.

Reefs originating through human activities, whether associated with dredged material banks from channels, oil field development, or purposeful creation (i.e., artificial reefs), appear not to vary in quality from natural reefs. Rates of accretion and loss were location-specific rather than dependent on the mode of origin of the reef. Clearly, artificial reefs can be markedly successful, if sited correctly to enhance reef growth (Powell et al., 1994).

There were substantial changes in bathymetric relief attributable to oysters in only one area, Redfish Bar, which has essentially moved south since the turn of the century (Powell et al., 1994). Relief on the remaining barrier reefs has not changed perceptibly. The reason for the disappearance of the original Redfish Bar cannot be precisely identified, nor are data sufficient to describe possible recovery of the many smaller reefs in East Bay and Trinity Bay that were impacted by shell dredging prior to 1970.



Source: After Powell et al., 1994

FIGURE 7.9b. *Diagrammatic representation of significant oyster reef gains and losses, 1970s to 1991.*

Large-Scale Impacts to Oyster Reef Habitat

Certain components of the Galveston Bay reef system have persisted throughout recorded time; others have exhibited substantial malleability, changing position and shape over time spans of a half century or so in response to natural and man-made changes in the bay system. Oysters respond to changes in circulation and current structure, **standing crop** and productivity of their phytoplanktonic food supply, salinity, and disease and predation (see Chapter Eight). Some of the most important large-scale changes to oyster habitat are presented below and shown above in FIGURE 7.9b.

Effects of the Oyster Fishery

No evidence exists for a substantial impact by the commercial oyster fishery on the bathymetric relief of existing oyster reefs (Powell et al., 1994). Supporting evidence provided from the survey included the following: 1) some of the most heavily-fished reefs have clearly not varied much in relief since an original 1850s survey (U.S. Coast Guard Service, 1855); 2) on the average, heavily fished reefs have accreted more area in the past 20 years than reefs not fished; 3) relief did not uniformly vary between reefs that are both open and closed to harvest for public health reasons–some of each had relatively high relief (one to 1.5 m) and low relief (<0.5 m), primarily controlled by local conditions and individual reef history; and 4) the most significant areas of reef loss were in areas of the bay closed for oyster harvesting (see Chapter Nine for a discussion of reef closures).

The data demonstrated several likely impacts on reef area by the fishery. Most leases today contain reef or semi-consolidated shelly areas, and at least some of this material originated from purposeful and inadvertent shell transplanting by the lease holders. The accretion or loss of these reef areas were, once again, dependent on siting in relation to natural factors affecting oysters; they were not dependent upon mode of origin. Movement of shell off reef edges, if anything, has appeared to aid in reef growth–many reefs in naturally favorable areas were accreting area at their margins. An unknown portion of this marginal accretion was due to shell movement by the fishery, but there was no evidence of reef loss by this mechanism. Accordingly, the areal extent of reefs has probably been increased by fishing activities (Powell et al., 1994). The evidence suggests that judicious siting of new leases and requirements for private shell planting on leases could substantially increase the acreage of reef in the Galveston Bay system.

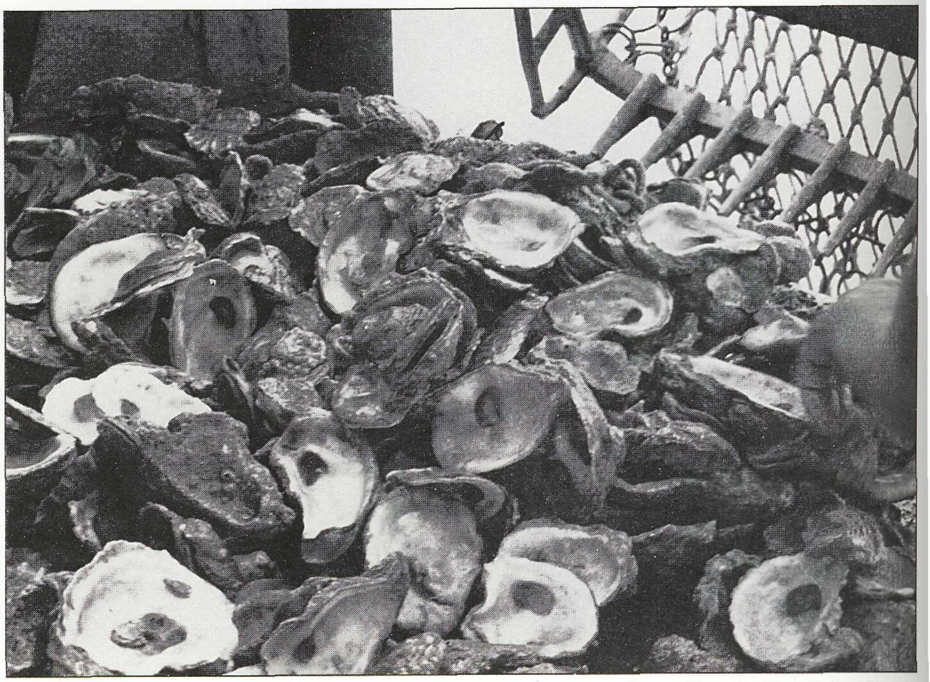
As a result of circulatory changes in the estuary (discussed below) some reefs are no longer optimally located for continued high productivity. Conversely, some areas with few oysters could now support productive reef if sufficient hard substrate became available. Observations suggest that naturally, reefs build only slowly out onto muddy bottom, due to the influence of several negative processes (Powell et al., 1989). This slow process of shell consolidation may make reefs susceptible to damage from commercial dredging during the early stages of their development, suggesting a conservative management approach for these areas.

Effects of Subsidence

Regional subsidence has increased the depth of Galveston Bay and changed its shape (see Chapter Five). Influences on oysters were reported by Powell et al. (1994) as threefold: 1) most reefs are now detached from the shoreline, a likely result of subsidence and shoreline retreat; 2) the increase in water depth (particularly for barrier reefs) has reduced the extent to which reefs are intertidally and subaerially exposed, while drowning the natural alongshore berms that can develop into reefs; and 3) areas of high subsidence, such as the Clear Lake Embayment, have suffered reef attrition due to siltation (FIGURE 7.9b). The Clear Lake area, however, must not be adequate to support reef growth any longer–otherwise reef growth would have kept up with siltation.

Effects of Channelization

Channelization, dike construction, and loss of the original Redfish Bar (see Chapter Five) have substantially altered bay circulation patterns. The pre-1900 circulation pattern in Galveston and Trinity Bays is unknown, but the breaching of Redfish Bar by the Houston Ship Channel likely produced major circulatory changes influencing oysters. Prior to 1900, Redfish Bar had three primary channels, only one of which (West Pass) admitted significant water interchange between the upper and lower bay systems. In all likelihood, a salinity gradient existed such that the upper bay system was substantially fresher than today. Other changes have probably also been important, for example, the Texas City Dike has probably reduced circulation in West Bay.



Source: Texas Sea Grant College Program

Oysters are harvested with oyster dredges (upper right). The live oysters are then separated from shell (predominating in this haul) and shucked for sale. Oysters require a hard substrate (generally shell) to grow, and changes in bay circulation can result in the demise of old reefs and the creation of new ones.

Bay-wide changes in circulation have resulted from these alterations. Today, the bulk of the Trinity River flow exits Trinity Bay along the southern shore, wraps immediately around Smith Point, and flows across Mattie B. Reef and Tom Tom Reef, reaching nearly to Bolivar Peninsula before becoming entrained in the seaward-flowing water at Bolivar Roads (FIGURE 7.9a). This circulation pattern has likely existed for many decades (Reid, 1955; Diener, 1975), but its intensity must have dramatically increased as the Houston Ship Channel became deeper and Redfish Bar ceased to function as a circulatory barrier.

For oysters, the result has been a destruction of the original equilibrium between reefs and the bay circulation (Powell et al., 1994). Ultimately, this change resulted in: 1) loss of a number of small reefs along the southern shore of Trinity Bay; 2) the demise of the Hanna Reef tract in the vicinity of Mattie B. Reef and Tom Tom Reef, the present outlet for much of the Trinity River flow;

and 3) the accretion of reef along the southern edge of South Redfish Reef, along the western and northern margin of Pasadena Reef, and along the southern edge of Bull Hill and associated reefs (FIGURE 7.9b). These latter three areas adjoin the present route of outflow of the Trinity River as it crosses the present barrier reef complex in the bay.

On the positive side, the Houston Ship Channel has also increased the penetration of more saline water up-estuary and has increased current velocities, extending the area of oyster productivity northward. Over 2,500 ac of reef have developed along this channel, a substantial fraction of which occurs between the shoulder of the channel itself and the crest of the parallel disposal banks (FIGURE 7.9b). Curiously, the data reveal the importance of the coincidence of two bathymetric features for development of reef along channels: both a channel and a dredged material disposal bank are required. Observation of channels in which the dredged material disposal banks were placed on only one side show that reef development is predominantly or exclusively on that side. In the reach from buoy 63 to Morgans Point, all reef development is in this small zone parallel to the channel. The reefs resulting from these alterations have greatly benefited the commercial fishery.

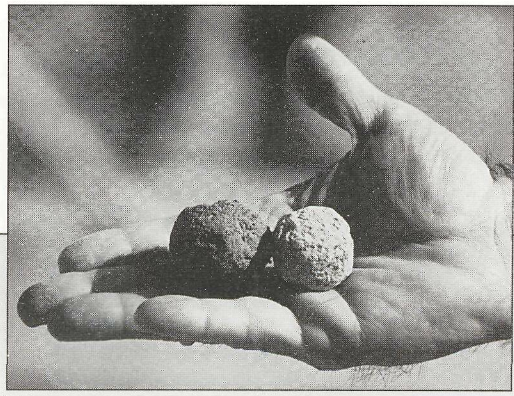
SUMMARY

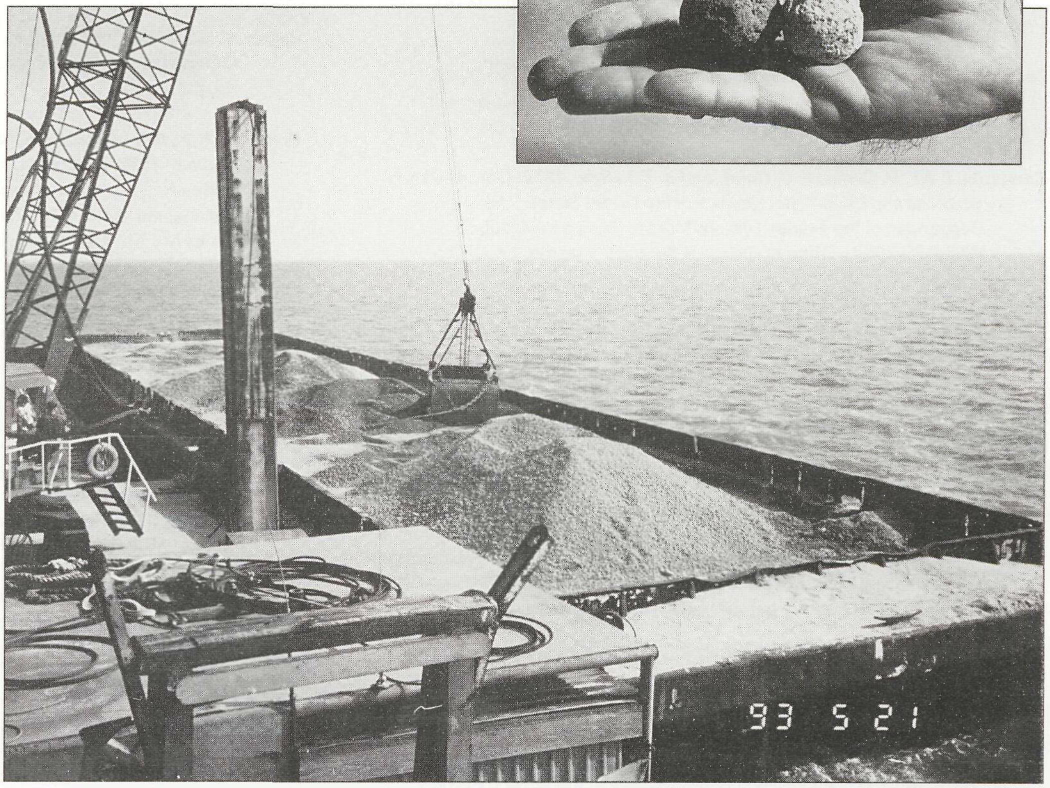
Wetlands and oyster reefs are two important habitat types within the Galveston Bay ecosystem. Wetlands have declined substantially over the past four decades, while oyster reefs appear to have increased.

Wetland losses are reflected by acreages of 171,000 in the 1950s; 146,500 in 1979; and 138,600 in 1989. The rate of loss, however, decreased over time from 1,000 ac/yr between 1953 and 1979, to less than 700 ac/yr between 1979 and 1989. Adjustments for photointerpretation errors reduce this rate even more. Most of the loss of estuarine marsh has been caused by subsidence and subsequent conversion to open bay/barren flats. For fresh water marshes, human activities have been responsible for most of the loss, particularly conversion to upland range. Other major alterations have resulted from a series of projects that have isolated a total of 16,000 ac of formerly estuarine marshland and shallow water from the bay. The closure of Turtle Bay (now called Lake Anahuac) in 1936 is the most prominent example of isolation.

Historically, continuous beds of submerged aquatic vegetation flourished around the Trinity River Delta, along the west shoreline from Seabrook to San Leon, and in West Bay. Only a remnant of this habitat remains in the submerged aquatic vegetation meadows of Christmas Bay, a secondary bay of west Galveston Bay. The exact reasons for the decline are still unknown, although increased turbidity, subsidence, increased erosion through wave energy, pollution, nutrient fluctuations, and human impacts have been identified as potential causes.

Overall, Galveston Bay has grown substantial oyster reef in the last 20 years. The location and mechanisms of reef accretion suggest that natural responses to changes in circulation and salinity by the oyster populations are primarily responsible, rather than the direct production of new reef by man. For example, the Houston Ship Channel has increased the penetration of saline water up-estuary, increasing the overall area of oyster reef by about 2,500 ac, to the great benefit of oyster populations and the oyster fishery.





Source: Houston Lighting and Power

Oyster studies suggest reefs can develop in some bay locations currently devoid of oysters due to lack of hard substrate. The Galveston Bay National Estuary Program, in conjunction with Houston Lighting and Power and the Port of Houston Authority, undertook a pilot project in which golf ball-sized pellets of coal ash were placed in the bay for reef-substrate. Preliminary results indicate this activity can make use of an industrial byproduct to benefit the bay.

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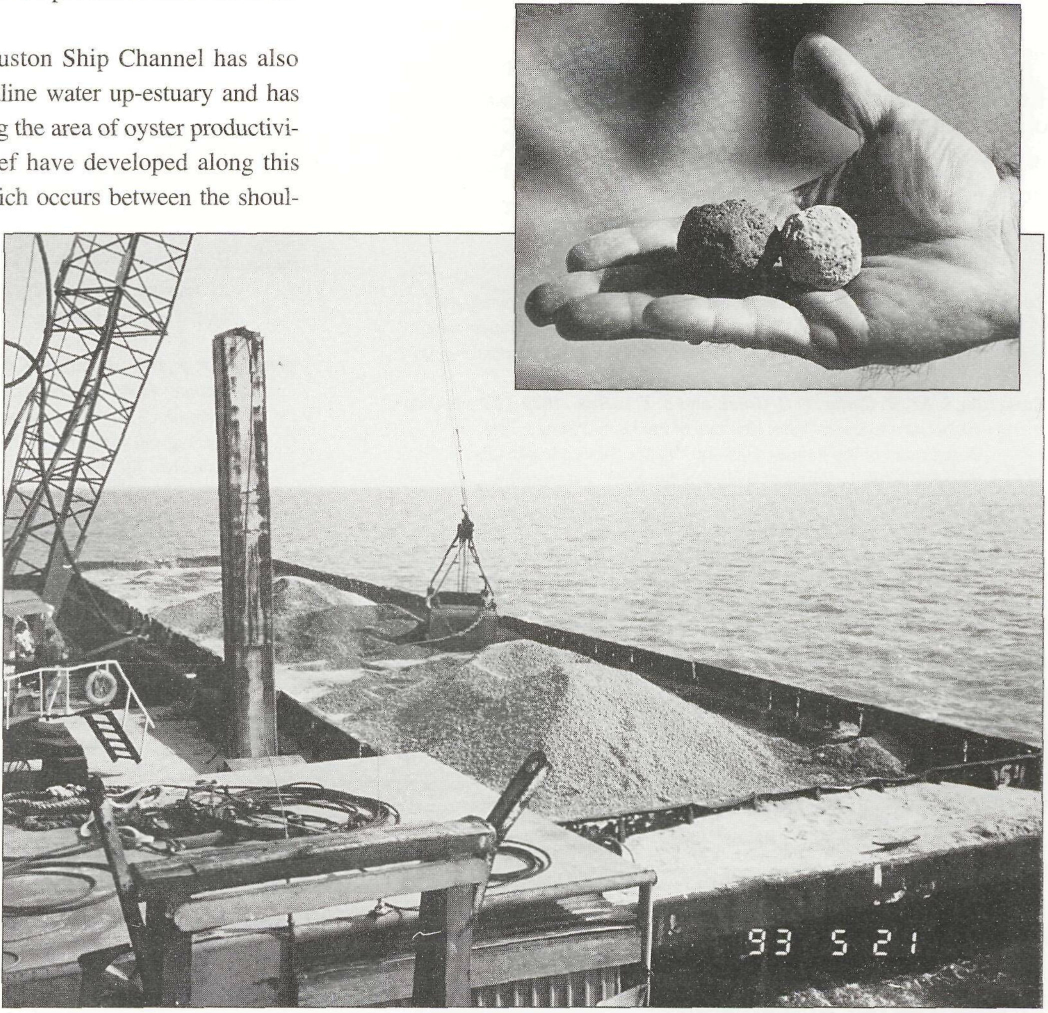

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